

Probing the Isotropy in the Sky Distribution of the Gamma-Ray Bursts

Attila Mészáros¹, Zsolt Bagoly², Lajos G. Balázs³, István Horváth⁴, and Roland Vavrek³

¹ Astronomical Institute of the Charles University, V Holešovičkách 2, CZ-180 00 Prague 8, Czech Republic

² Laboratory for Information Technology, Eötvös University, Pázmány Péter sétány 1/A, H-1518 Budapest, Hungary

³ Konkoly Observatory, Box 67, H-1505 Budapest, Hungary

⁴ Department of Physics, Bolyai Military University, Box 12, H-1456 Budapest, Hungary

Abstract. The statistical tests - done by the authors - are surveyed, which verify the null-hypothesis of the intrinsic randomness in the angular distribution of gamma-ray bursts collected at BATSE Catalog. The tests use the counts-in-cells method, an analysis of spherical harmonics, a test based on the two-point correlation function and a method based on multiscale methods. The tests suggest that the intermediate subclass of gamma-ray bursts are distributed anisotropically.

1 Introduction

At the last years the authors carried out several statistical tests in order to verify the isotropy of the angular distribution of the gamma-ray bursts (GRBs) collected at BATSE catalog ([6]). In this contribution we collect the results of them; these results were partly published in several articles ([1], [2], [7], [8], [9]).

2 Tests

Spherical harmonics

The key idea of this test is based on the fact that the sky-exposure function of BATSE instrument is not depending on right ascension. Therefore in equatorial coordinates the theoretically expected values of spherical harmonics of the distribution of GRBs are zeros for any $m \neq 0$ term. Then these expectations are tested.

Counts-in-cells

This is a simple statistical test. The idea is the following: The sky is separated into equal areas, and then, e.g., χ^2 test is used to test the null hypothesis of isotropy. The sky-exposure function can be eliminated by the use of equatorial coordinates; then "effective" equal areas are taken. For example, if the sky is separated into 8 equal areas, then the boundaries are $\alpha = 0, 90, 180, 270$ degrees, and $\delta = -30.8, +1.5, +33.6$ degrees (instead of $\delta = -30, 0, +30$ degrees).

Two-point angular correlation function

The key idea of this method is the following. Having N GRBs on sky we have $N(N-1)/2$ angular distances among them. If N GRBs are distributed randomly, then these distances should be distributed randomly, too. Then the observed distances are compared with the pseudo-randomly generated $N(N-1)/2$ distances coming from Monte Carlo simulations, which are provided in accordance with the sky-exposure function. Hence, the sky-exposure function is eliminated by Monte Carlo simulations.

Multifractal analysis, minimal spanning tree, Voronoi tessellation

For the detailed description of these three methods see the contribution [10] in this Proceedings.

3 Results

The results of done tests for the three subclasses ([5], [4]) of GRBs separately are collected at Table 1.

Table 1. Survey of the results of the isotropy tests. The question "Is the null hypothesis rejected?" is answered. When the answer is "Yes", then the significance level of rejection is also given. We required a higher than 95% level.

short $T_{90} < 2s$	intermediate $2s < T_{90} < 10s$	long $T_{90} < 10s$	
No	Yes > 97%	No	Spherical harmonics
No	Yes > 96.4%	No	Counts-in-cells
Yes > 99.2%	Yes > 99.8%	Yes > 99.8%	Two-Point Correlation
No	Not done	Not done	Voronoi tessellation
No	Not done	Not done	Minimal spanning tree
Yes > 99.9%	Not done	Not done	Multifractal analysis

The done tests of isotropy suggest the existence of **anisotropy for the intermediate subclass** on the confidence level $> 95\%$.

For the remaining two subclasses the situation is unclear; there is no unambiguous rejection of isotropy for them yet on the higher than 95% confidence level. It can only be said that the short subgroup is highly "suspicious".

4 Conclusions

The long GRBs seems to be distributed isotropically - the positive result from two-point angular correlation function is probably an unknown instrumental effect.

For the short GRBs the isotropy is not rejected yet on a satisfactorily high confidence level, but there are indications for the anisotropy both from the the multifractal analysis and also from the two-point angular correlation function. Add also that the statistical comparison of the short and the intermediate + long subgroups also suggests anisotropy here [1], [2]. Simply the situation is highly "suspicious" here. Note still that the shortest "tail" $T_{90} < 0.1$ s, which is doubtlessly anisotropic [3], was not considered separately.

The intermediate subclass [4] **is anisotropic**; only the concrete value of confidence level is a question - it "fluctuates" between 96.4 - 99.9 %. The character of anisotropy of intermediate subclass is incomprehensible, because the "dimmer" half of this subsection is more anisotropic [8]. In addition, there is no concentration toward the Galactic or Supergalactic planes.

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